

Eco-friendly dyeing of cellulosic fabric using Direct Red 28 and Direct Blue 15 dyes

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Graphical abstract



Abstract

Sustainability in textiles is now a day's key demand of consumers and traders, where the process with zero effluent emission or less emission has been considered for aim to utilize the ecofriendly process in direct dyeing of cotton to minimize effluent load. For this purpose, variable amount of Table salt and Glauber salt has been used to achieve maximum exhaustion during direct cotton dyeing. Different dyeing variables have been employed; shade made at the optimum conditions were assessed according to ISO standards. It has been found that 3 g/100 mL of table salt for Direct dyeing of cotton using 40 mL of DR 28 (8 pH) at 65 °C for 45 min, whereas using 40 mL of DB 15 (8 pH) for dyeing of cotton at 65 °C for 45 min containing 3 g/100 mL of Glauber salt has given acceptable color characteristics. The reduction in dyeing variable using low salt amount has proved that this method is cost, time and energy efficient process, which can be utilized for dyeing of natural fabrics using various classes of dyes to obtain sustainable textile products.

Keywords: Cotton, colorfastness, Direct Red 28, Direct Blue 15, Glauber salt, sustainability, table salt.

1. Introduction

Textile industry is the economic hub of global community (Zhou *et al.*, 2017). Textile and apparel industry usually rely on synthetic dyes for production of finished goods. Due to brighter and sharper shades of synthetic dyes, they appeal human nature deeply (Tawfik and Rehan, 2018). According to a comprehensive research, about 7×10^8 Kg per annum synthetic dyes are manufactured worldwide. Synthetic dyes are required to meet the human demands off sharp and beautiful colors in the field of textiles, increased awareness of environmental issues demands

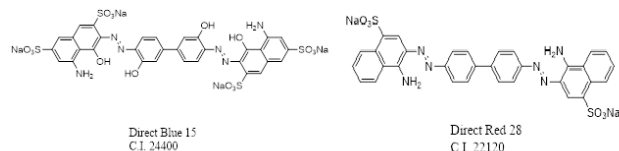
methods to be adopted to reduce effluent load and to attain higher rate of fixation adequate amounts of salts are used (Rosa *et al.*, 2019; Kim *et al.*, 2019). Dyes are classified on the basis of color, structure and mode of application. Depending upon the mode of application of dyes, Acid dyes, Basic dyes, Disperse dyes, Reactive dyes, Sulfur dyes, vat dyes and direct dyes are widely available. Among all the dyes Direct dyes have their own importance. For the production of clothing at local level, Direct dyes are mainly favored due to their comparatively low cost, minimal energy consumption, water solubility fine light fastness, comparable in application, shorter dye cycle, low cost of auxiliaries, remarkably lesser use of water and much lower salt level in effluent (Deshuai *et al.*, 2017). After treatments of fabric dyed with Direct dyes yield better fastness properties. Direct dyes is anionic class of dyes having good attraction for cellulosic and protein fibres. Direct dyes include chemically different groups the most common ones are azo, anthraquinone and phthalocyanine dyes (Yusra and Nawaz, 2010). Textile industry today mainly favors dyeing of cellulosic and protenous family like cotton, yarn and silk etc. Apparel industry uses cotton fibres the most about 50%.

Certain auxiliaries are used to make dyeing process smooth and effective. Most important auxiliary used in direct dyes is concentration of electrolyte. Salts are important auxiliary as it lowers zeta potential, exhaustion of dye is directly proportional to concentration of electrolyte and it tends to absorb dye molecules on fabric (Debasree *et al.*, 2018). Usually sodium salts are used as an electrolyte in dyeing because of their low cost and easy availability. In present study our focus is on the influence of Table salt (NaCl) TS and Glauber's salt (Na₂SO₄) GS in direct dyeing of cotton using Direct Blue 15 and Direct Red 28. As both these salts (NaCl) TS and (Na₂SO₄) GS are water soluble and produce sodium ions their effect is almost same except the anion produced (Burkinshaw and Salihu, 2019a). In case of Table salt chloride ions cause corrosion of dyeing medium. On the other hand sulfate ions of Glauber salt cause repulsion between negatively charged sulphonic groups of dye.

2. Materials and method

2.1. Sample preparation

Direct Red 28 (DR 28; C.I 22120) and Direct Blue 15 (DB 15; C.I 24400) dye was provided by Paragon Dyes & chemicals Faisalabad Pakistan and other chemicals such as NaCl, HCl, Na_2SO_4 , Na_2CO_3 , neutral soap and wetting agent etc. used were of local grade (Pak Made) were used in this study were produced from by Pakistan scientific store (Pvt. Ltd.), Faisalabad, Pakistan). Mil treated plain cotton fabric was obtained from Noor Fatima Fabric Faisalabad, Pakistan.



2.2. Dyeing process

2.2.1. Effect of salt on direct dyeing

Using two dyes effect of salt Table salt (NaCl; T.S) and Glauber salt (GS; Na_2SO_4) were observed. For the purpose of table salt was added 1 g/100 ml during dyeing of cotton with DR 28 dye keeping dye solution to cotton fabric ratio 1:25 at 60 °C for 60 min (Tarikul *et al.*, 2017). Same process was repeated using DB 15 solution. After dyeing, hot & cold water washing was given to dyed fabric three times, dried & subjected to spectra flash for K/s & Lab values. All the process done was same except for both dyes that the concentration of table salt (NaCl) were 2, 3, 4, 5 g/100 ml instead of 1 g/100 ml for making comparison 1–5 g/100 ml of Glauber salt (Na_2SO_4) was used as exhausting agent for both dyes (Burkinshaw and Salihu, 2019; Paul *et al.*, 2017).

2.2.2. Effect of temperature on direct dyeing

Temperature of dye bath was optimized by dyeing 1 g of fabric using DB 15 containing 3 g/100 ml of table salt (NaCl) & Glauber salt (Na_2SO_4) keeping dye liquor to fabric ratio 1:25 at 35 °C. All the process of dyeing was same except the heating level was 45 °C, 55 °C, 65 °C, 75 °C, 85 °C instead of 35 °C. To observe the role of NaCl (TS) and (Na_2SO_4) GS on dyeing the fabric (1 g) was dyed with DR 28 containing 3 g/100 ml of GS at 35 °C. All the process of dyeing was same except the heating level was 45 °C, 55 °C, 65 °C, 75 °C, 85 °C instead of 35 °C.

2.2.3. Effect of dyeing period on direct dyeing

Contact time is optimized by dyeing 1 g of fabric using DR 28 dye containing 3 g/100 ml of (NaCl) TS and (Na_2SO_4) GS at 65 °C keeping dye liquor to fabric ratio 1:25. All the process of dyeing was same except the contact period was 30, 45, 60 min instead of 15 min. To optimize the dyeing period using DB 15, 1 g of fabric was dyed using 3 g/100 ml (NaCl) TS and (Na_2SO_4) GS at 65 °C for 15 min. All the process of dyeing was same except the contact period was kept 30, 45, 60 min instead of 15 min.

2.2.4. Effect of pH on direct dyeing

pH of dye bath is optimized using DB15, 1 g of fabric was dyed for 45 mins using (NaCl) TS and (Na_2SO_4) GS at 65 °C keeping liquor to fabric ratio 1:25 keeping pH of dye bath

5. Similarly, all the process was done keeping all conditions were same except pH of dye bath was 6, 7, 8, 9, 10, 11 instead of 5 pH. Moreover, optimization of pH is done using DR 28 by dyeing 1 g of cotton fabric for 45 min using (NaCl) TS and (Na_2SO_4) GS at 65 °C keeping liquor to fabric ratio 1:25 maintaining dye bath at pH 5. All the process was repeated same except pH of dye bath was 6, 7, 8, 9, 10, 11 instead of 5 pH.

2.2.5. Effect of volume on direct dyeing

Volume of dye bath was optimized by employing 10 ml of DR 28 for 1 g of cotton containing 3 g/100 ml of (NaCl) TS and (Na_2SO_4) GS at 65 °C for 45 min keeping pH of dye bath at 9 pH. Similarly, all dyeing conditions were kept same using 20, 30, 40, 50, 60 ml of dye volume instead 10 ml. In another series of experiments 10 ml of DB15 was employed for 1 g of fabric containing 3 g/100 ml of TS (NaCl) and GS (Na_2SO_4) at 65 °C for 45 mins at pH 9 (Haque, 2015). Similarly, all dyeing process was same using 20, 30, 40, 50, 60 ml of dye volume instead 10 ml.

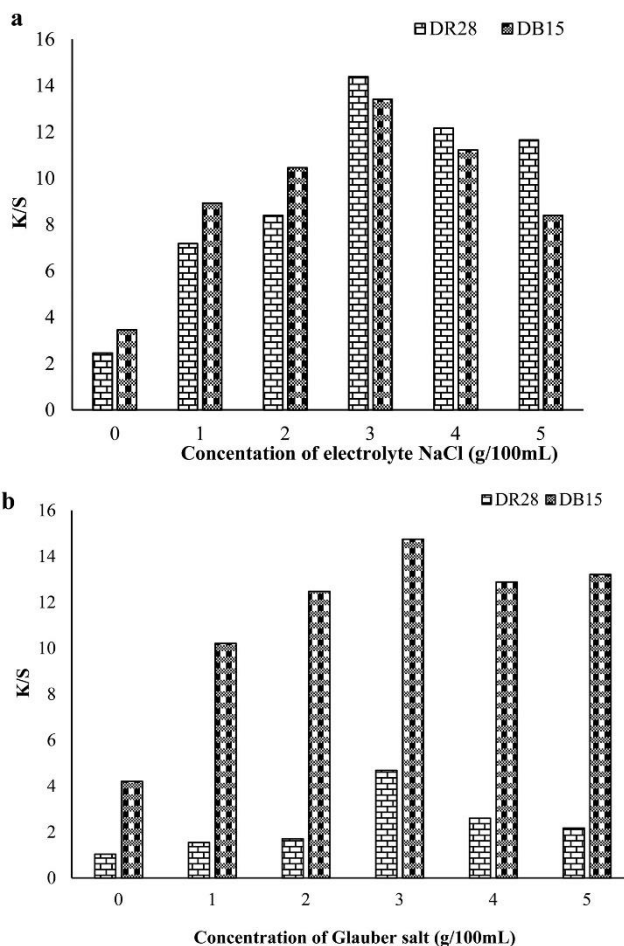


Figure 1. a. Effect of Table salt on dyeing of cellulosic fabric with Direct Red (DR)28 and Direct Blue (DB)15 dye. b. Effect of Glauber salt on dyeing of cellulosic fabric with Direct Red (DR)28 and Direct Blue (DB)15 dye

2.3. Analysis of undyed fabric & dyed fabric

The change in characteristic peak of fabric before and after dyed fabric was taken through Fourier-transform infrared spectroscopy FTIR. For color strength value of all dyed fabric were assessed in specter flash (SF 600), at

Department of Applied Chemistry Government Collage University Faisalabad, Pakistan. The color fastness properties of the dyed fabric at optimum conditions were rated at grey scale using standard method of ISO.

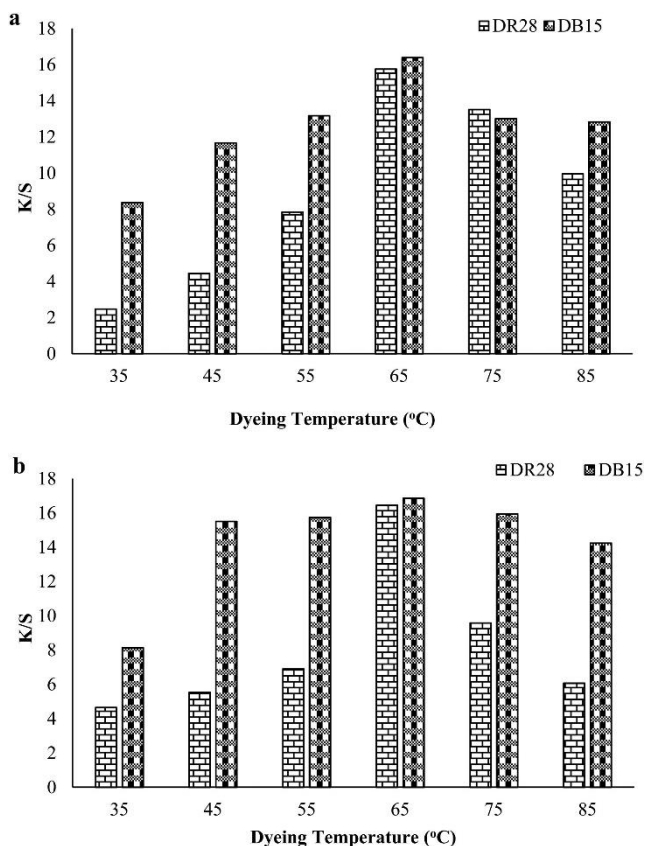


Figure 2. a. Effect of Table salt on heating for dyeing of cotton using Direct Red (DR)28 and Direct Blue (DB) 15 dye. b. Effect of Glauber salt on heating for dyeing of cotton using Direct Red (DR)28 and Direct Blue (DB)15 dye

3. Results and discussion

3.1. Effect of salt

It is found that direct dyes are used to dye cellulosic fibres initially their sub stativity towards less without presence of salt (Samera Salimpour Abkenar *et al.*, 2015). This is because when fabric is immersed in solution it gets negative charge due to which it repels molecules and upon dyeing low fixation is observed in presence of salt this negative charge on the fabric may be neutralized by adding salt to facilitate the dye for form interaction within range of short attractive force (Tarikul *et al.*, 2017). Thus addition of salt results in excellent exhaustion which yields good color strength. The results given in (Figure 1a) revels that using 3 g/100 ml table salt using DB 15 and DR 28 has exhausted dye bath well there by yielding excellent color strength. Low amount of salt doesn't evolve the color from dye bath to move towards fabric, whereas to much high amount may promote over exhaustion due to which sudden aggregation dye molecule may results in poor proper fixation which upon washing the unfixed colorant molecules ate washed at low shade is observed. The brightness of shades using Glauber’s salt has been

changed due to larger extent of repulsion between sulphate ions of dye and electrolyte (Burkinshaw and Salihu, 2019). The result given in (Figure 1b) revels that using 3 g/100 ml glauber salt produced good color strength on cotton fabric.

3.2. Effect of temperature

Direct dyeing of cotton is always temperature dependent because only a certain heating level accelerate dye bath kinetics with gradual rise of heating, the molecules become activate only up to certain level gain high kinetic energy to sorb onto fabric (Grande *et al.*, 2017). But after certain level, the rate of dyeing which is present in equilibrium with rate of decomposition become recessive for low tint (Bhatti *et al.*, 2014; Batool *et al.*, 2011). The results given in (Figure 2a) reveal that dyeing of cotton at 65 °C has given excellent results using TS (3 g/100 ml) as exhausting agent using DR 28 and DB15. By application of Glauber’s salt, it refers changing in brightness of shades because the nature of the salt has taken molecules towards fabric through different way. It is noticed that using DR 28 and DB 15 using GS 3 g/100 ml as electrolyte showed excellent result at 65°C (Debasree *et al.*, 2017). The results are given in Figure 2b.

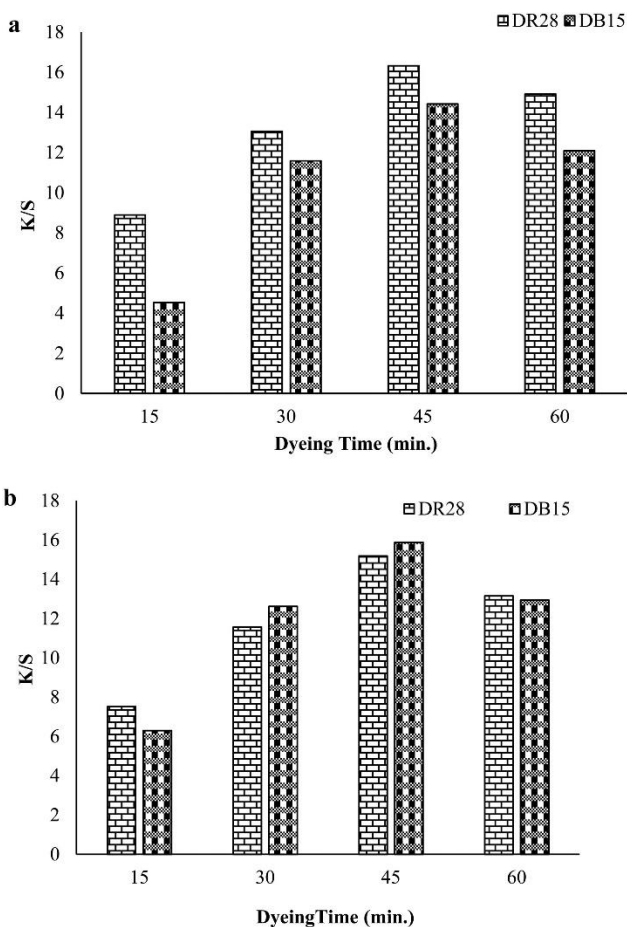


Figure 3. a. Effect of Table salt on contact level for dyeing of cotton using Direct Red (DR)28 and Direct Blue (DB)15 dye. b. Effect of Glauber salt on heating for dyeing of cotton using Direct Red (DR)28 and Direct Blue (DB)15 dye

3.3. Effect of time

The rate of direct dyeing is always prone to some levels particularly time and temperature. Heating for short time does not activate the dye molecules to rush towards the fabric, whereas for long time heating the molecules may start removing from fabric to dye bath due to rise in rate of desorption instead of dyeing (Hauq *et al.*, 2014). Hence dyeing for optimum level is recommended to get desired results. The data displayed in (Figure 3a) using Table salt and (Figure 3b) using Glauber's salt reveal that dyeing of cotton for 45 minutes has given excellent results using DB15 and DR 28. Dyeing for low time produces low tint (Amato *et al.*, 2018). Whereas dyeing for much higher time also produces low tint due to desorption process of dye (Adeel *et al.*, 2017).

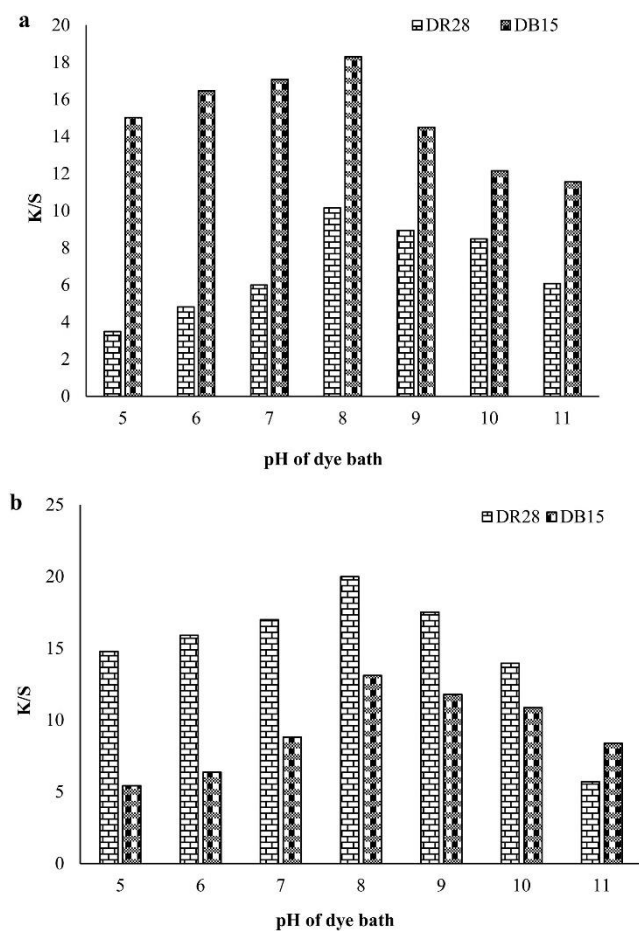


Figure 4. a. Effect of dye bath pH on dyeing of cellulosic fabric with Direct Red (DR)28 and Direct Blue (DB)15 dye using Table salt. b. Effect of dye bath pH on dyeing of cellulosic fabric with Direct Red (DR)28 and Direct Blue (DB)15 dye using Glauber salt

3.4. Effect of pH

Dye uptake ability of fabric like cotton is remarkably influenced by pH of dyeing medium in dyeing bath. Fabric immersed in water acquires negative charge, moreover, dye molecules in solution also have negatively charged groups, so there is repulsion between both fabric and dye molecules. pH of dye bath and electrolyte both affects in such a way that there increasing concentrations lowers the repulsion between fabric and dye molecular anions by

developing opposite charge on dye molecules, hence improves dye-ability. But too much high pH of medium cause greater repulsion between high concentration of hydroxide ions of alkaline medium and $-OH$ ions of fabric (Sun *et al.*, 2017; Ngulube *et al.*, 2017). From (Figure 4a) using Table salt and (Figure 4b) using Glauber's salt, excellent color strength is given at pH 9. It is concluded that appearance of shades improves greatly by increasing pH of dyeing medium. But very high value pH of alkaline medium cause significant increase in repulsion between anions of dye and cellulose.

3.5. Effect of dye volume

The salt effect is always prominent on the direct dyeing of cotton using DR28. The utilization of salt for exhaustion of particular volume to get desired result depending upon nature of dye, it's made of action table salt used has taken 40 ml of dye for maximum exhaustion towards fabric (Burkinshaw and Salihu, 2019b). Low value does not cause sorption of dye to much extent due low context, whenever to much volume of dye bath accumulation of dye molecules at greater extent in the form of aggregates. Then aggregates found much difficulty in sorption of fabric (Irfan *et al.*, 2018). The data given in (Figure 5a) using Table salt and (Figure 5b) using Glauber's salt reveals that dyeing of cotton gives excellent results using 40 ml solution of 1% solution of DB15 and DR 28.

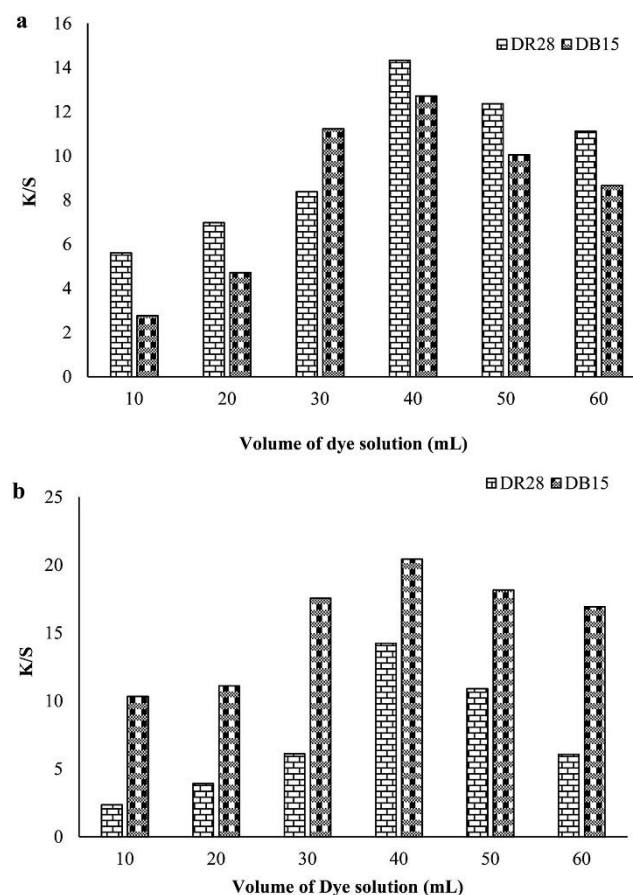


Figure 5. a. Effect of volume of dye bath on dyeing of cellulosic fabric with Direct Red (DR)28 and Direct Blue (DB)15 dye using Table salt. b. Effect of volume of dye bath on dyeing of cellulosic fabric with Direct Red (DR)28 and Direct Blue (DB)15 dye using Glauber salt

3.6. Fastness properties

The rating results given in Table 1(a) for shades using Direct Red 28 DR 28 dye and Table 1(b) for shades using Direct Blue 15 DB 15 dye, reveal that Table salt TS and Glauber salt GS utilization to achieve maximum exhaustion at given dyeing conditions have been improved. Good light, wash and rubbing fastness can be attributed to the presence of conjugation systems, benzenoid rings, auxochromes and the mode of bonding (Ijaz *et al.*, 2014; Adeel *et al.*, 2015).

The cellulosic fabric always shows good resistance after leveling dyeing with Direct Red 28 and Direct Blue 15, because big dye molecules may find good penetration, there by firm fixation yield good shade. Similarly, colorfastness to perspiration and dry cleaning also affected by molecular size, dyeing process, nature of fabric as well as presence of auxiliaries during dyeing (Kiran *et al.*, 2019). Hence all this fastness jointly adds value in coloration of fabric using Direct Red 28 and Direct Blue 15 at optimal conditions and examine colorfastness characteristics.

Table 1. (a) Rating of fastness properties of dye fabric using Direct Red 28 dye. (b) Rating of fastness properties of dye fabric using Direct Blue 15 dye

Shades	NaCl						Na ₂ SO ₄							
	LF	WF		RF		DCF	PF	LF	WF		RF		DCF	PF
		C.C	C.S	DRF	WRF				C.C	C.S	DRF	WRF		
(a)														
1	4	4	3/4	4/5	4/5	4/5	4/5	5	4	3/4	4/5	4/5	4/5	4/5
2	4/5	4	3/4	4/5	4	4	4/5	5	4/5	4	5	4/5	4/5	4/5
3	4/5	4	3/4	4/5	4	4	4/5	5	4/5	4	5	4/5	4/5	4/5
4	4/5	4	3/4	4/5	4	4	4/5	5	4	3/4	4/5	4/5	4/5	4/5
5	4/5	4	3/4	4/5	4	4	4/5	5	4	3/4	4/5	4/5	4/5	4/5
(b)														
1	4	3/4	3/4	4	3/4	4/5	4/5	4/5	4	3/4	4/5	4	4	4/5
2	4	3/4	3/4	4	3/4	4	4/5	5	4/5	4	5	4/5	4	4/5
3	4/5	3/4	4	4	3/4	4	4/5	5	4/5	4	5	4/5	4/5	4/5
4	4/5	3/4	4	4	3/4	4	4/5	5	4/5	4	4/5	4	4/5	4/5
5	4/5	3/4	4	4	3/4	4	4/5	5	4/5	4	4/5	4	4/5	4/5

LF = Light Fastness, WF = Wash fastness, DRF & WRF = Dry & Wet wash fastness, DCF = Dry clean fastness, PF = Perspiration fastness

4. Conclusion

The global community due to spread awareness of sustainability is following such processes and products which are green and clean with low effluent load as well as cost, time and energy effective. In this study method employed has shown excellent results onto cellulosic fabric Direct Red 28 and Direct Blue 15 dyes, where the utilization of low salts has exhausted colorant molecules to much extent towards fabric there by reducing levels of dyeing variables. This study concluded that by employing this method not only coloration of natural fabrics using other classes of dyes can be made ecofriendly for global community, but also acceptable color characteristics can be achieved.

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